The Relative Benefits From The IM240 And ASM Tests Performed On Vehicles Tested In CARB's I&M Pilot Program

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ABSTRACT

The United States Environmental Protection Agency (USEPA) in its November 5th, 1992 regulation for state-operated motor vehicle Inspection and Maintenance (I&M) programs, set forth performance standards for both "basic" and "enhanced" I&M programs. Enhanced programs, required in areas that are in serious or extreme nonattainment for Ozone or moderate nonattainment for Carbon Monoxide (CO), are to achieve a twenty-eight percent reduction in Volatile Organic Compounds (VOC), a thirty-one percent reduction in CO and a nine percent reduction in Oxides Of Nitrogen (NOx). The USEPA suggested the establishment of centralized test only stations and a network of decentralized repair shops to meet the performance standards for an enhanced I&M program. Additional stipulations to the enhanced I&M program require that 1986 and newer model year vehicles be tested using the IM240 transient cycle.

The State of California, concerned about implementing a test which could not easily be reproduced by repair facilities without incurring significant equipment costs, proposed the use of Acceleration Simulation Mode (ASM) steady state loaded mode tests as an option to meeting these performance standards. Since California's overall I&M strategy advocates that the majority of the fleet go through a decentralized test and repair program, the identification and the effectiveness with which repairs are performed using the ASM tests are issues that surfaced. An I&M Pilot Program was conducted by the California Air Resources Board (CARB) to assess the relative identification and repair rates from vehicles tested over the IM240 and ASM tests. This paper addresses the findings from this program.

BACKGROUND

The USEPA proposed the establishment of centralized test only stations and a network of decentralized repair shops to achieve the enhanced I&M performance standards. Additional enhancements to the I&M program require that the 1980 and earlier model year vehicles be tested using an idle test, 1981 through 1985 model year vehicles be tested using the idle and 2500 rpm no load tests, and 1986 and newer model year vehicles be tested using the IM240 transient cycle. The IM240 is a 240 second transient test during which a vehicle's tailpipe emissions are measured in grams per mile (g/mi). This test requires a dynamometer capable of full inertia weight simulation and a laboratory grade constant volume sampling system (CVS) to accurately measure the tailpipe emissions. The USEPA suggested the total separation of testing from repair to reduce the emission benefits lost from mechanics who are not motivated to perform the tests correctly or effect correct repair under the current decentralized testing and repair system.

The State of California, concerned about implementing a test which could not easily be reproduced by repair facilities, suggested an alternative I&M program that utilizes a high emitter profile (developed by the Bureau Of Automotive Repair, BAR) to identify vehicles most likely to fail and send these vehicles to centralized testing facilities. As it is currently envisioned, approximately 15 percent of the vehicles will be identified by the targeting profile. The remaining fleet of vehicles would go to decentralized test and repair facilities. In addition, remote sensing devices (RSD) will also be used to identify vehicles most likely to fail and send these vehicles for off-cycle inspections to centralized testing facilities. RSD will primarily be used to spot check the on-road fleet to ensure longevity of repair. California's alternative I&M program would require fewer centralized test only facilities, maintaining the majority of the decentralized test and repair facilities. In addition, California proposed the use of steady-state loaded mode tests (ASM5015[*] and ASM2525[**]), lower cost alternatives to the IM240 transient test, in both centralized and decentralized facilities to identify failing vehicles.

Since California's I&M program advocates that the majority of the fleet go through a decentralized test and repair program, the identification rate and the effectiveness with which repairs will be performed using the ASM tests were issues that surfaced. For vehicles going to a decentralized test and repair facility, the USEPA assumed a 50% disbenefit. This disbenefit was based on the assumption that mechanics in decentralized repair facilities have little incentive to either fail or properly repair vehicles, and that it may be easier for mechanics to pass a vehicle tested over the ASM than it may be over the IM240 cycle. The I&M Pilot Program, which was conducted at CARB's Haagen-Smit Laboratory (HSL) between June and December of 1994, was not designed to prove or disprove USEPA's assumption that the decentralized test and repair program is less effective than a centralized test only program. The main objectives of the I&M Pilot Program were to:

- Assure that a representative sample of the in-use vehicle fleet was procured for testing.
- Simulate conditions that may be encountered in a "real world" I&M program.
- Determine the percentage of vehicles identified as passing (CP), failing (CF), falsely failing (errors of commission or EC) and falsely passing (errors of omission or EO) by the IM240 and the ASM tests.
- Determine the percentage of excess emissions, by pollutant, identified by the IM240 and the ASM tests.
- Determine the percentage of excess emissions, by pollutant, reduced for vehicles repaired to the IM240 and the ASM emission cutpoints.

INTRODUCTION

The CARB and the USEPA entered into a Memorandum of Agreement (MOA) to finalize the I&M test plan. This test plan detailed how the IM240 and ASM cutpoints were established and how the data should be evaluated. The following sections briefly explain the overall test plan, equipment used in testing these vehicles, mechanics selection, and the establishment of the cutpoints.

Test Plan

Figure 1 shows the relevant portions of the test plan. Vehicle owners were asked to bring their vehicles to CARB's HSL, where the vehicle was first checked-in and a damage inspection report was prepared to shield CARB from unnecessary liability claims. Thereafter, a safety inspection was performed to determine if repairs were necessary in order to safely test the vehicle on a dynamometer. These repairs, labeled as pre-acceptance repairs, were performed to correct defective brakes, replace worn tires, correct wheel alignment and fix leaking exhaust systems. After pre-acceptance, the vehicles were tested over the IM240 and ASM tests. The sequence of these tests depended on the vehicle number assigned by CARB's HSL staff, odd numbered vehicles were tested over the IM240 first followed by the ASM tests and vice-versa for even numbered vehicles. After these screening tests the vehicles were given a BAR90 Smog Check test as an incentive to vehicle owners for their participation. After the BAR90 test, vehicles failing only the IM240 or ASM test were assigned to the IM240 and ASM bins, respectively. Vehicles that failed both tests were assigned according to the vehicle number, i.e., odd numbered vehicles failing both tests were placed in the IM240 bin. Vehicles passing both tests were placed into the passing bin. All the vehicles assigned to the IM240 and ASM bins and approximately 100 vehicles from the passing bin were tested over the Federal Test Procedure (FTP)[***] . Those vehicles that failed an ASM or IM240 test and subsequently

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[*] The Acceleration Simulation Mode ASM5015 test is a steady-state loaded mode test performed at 15 miles per hour (mph). The dynamometer load is set to simulate 50 percent of the road load required to accelerate the vehicle at 3.3 mph per second applied at 15 mph.

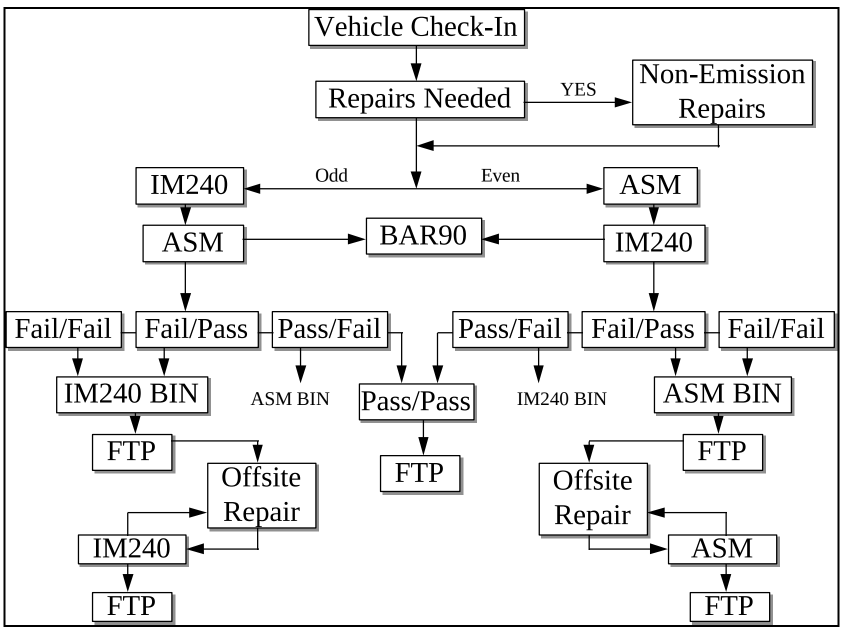
[**] The ASM2525 test is a steady-state loaded mode test performed at 25 miles per hour (mph). The dynamometer load is set to simulate 25 percent of the road load required to accelerate the vehicle at 3.3 mph per second applied at 25 mph.

[***] The FTP is a standardized test during which a vehicles emissions are measured at controlled environmental conditions.

passed the FTP test were considered as errors of commission for the ASM or IM240 test, respectively. Similarly, vehicles that passed the ASM or IM240 test and subsequently failed the FTP test were considered as errors of omission for the ASM or IM240 test, respectively.

Vehicles assigned to either the IM240 or ASM bin were sent to the off-site facility for either IM240 or ASM repairs. CARB established an off-site repair facility at Clayton Industries. This facility had two repairs bays, one for repairing ASM failing vehicles and one for repairing IM240 failing vehicles. The ASM and IM240 repair teams were provided with the initial screening test results for ASM and IM240 failing vehicles, respectively. The mechanics were asked to perform the repairs within a $500.00 repair limit and only repair vehicles to the extent necessary to pass the test. There was no repair limit for fixing tampered components. Additionally, mechanics were asked to use a $40 per hour labor rate and to base their labor hours using the Alldata* software. Following the off-site repair the vehicle was returned for confirmatory tests at CARB. If the vehicle failed this test then it was returned to the off-site facility for further repairs. This process of looping the vehicle between the repair facility and the centralized testing facility was allowed for a maximum for three times or until the repair cost limit was exceeded. The vehicle was then given a final FTP test to determine the emissions reduction after repair.

Figure 1 I&M Test Plan



Testing Equipment *used at CARB's HSL*

The IM240 and FTP tests were performed on water-brake and electric dynamometers capable of full inertia weight simulation. The exhaust emissions were measured using laboratory grade constant volume sampling systems.

The ASM tests were performed on electric dynamometers. The raw exhaust emissions were measured using Automotive Diagnostics (AD) BAR90 units. These units were modified with an Electro-Chemical Nitric Oxide Tester (ECNOT) supplied by Sensors, Inc. The basic guidelines for conducting an ASM test incorporated an emissions stabilization period, with a maximum time of 40-45 seconds, followed by a 30 second sampling time. During the sampling period the AD machine averages the emissions every 2 seconds printing 15 averaged emissions results. CARB staff used the average of the last 5 readings (ten seconds) to determine if the vehicle passed or failed. A single ASM test was usually completed within 60-75 seconds. However, there were instances in which the test was allowed to continue for up to 240 seconds.

* This software provides vehicle diagnosis and repair information and an estimate of the labor hours.

Testing Equipment *used at CARB's Clayton Repair Facility*

In accordance with the MOA, two repair bays were established at Clayton Industries.* This arrangement was necessary to address USEPA's concern that if ASM and IM240 mechanics worked together, then the ASM mechanics would benefit from the knowledge gained from the IM240 mechanics in repairing IM240 failing vehicles. Each repair bay was similarly equipped in order to minimize the interaction between the mechanics from each team. Each repair bay was equipped with the following:

- A repair grade electric dynamometer manufactured by Clayton Industries.
- Environmental Systems Products (ESP) dynamometer controller and repair grade emissions analyzer. ESP's emissions analyzer is a modified BAR 90 analyzer equipped with Sensors Inc. ECNOT analyzer.
- A Bear-Allen engine analyzer.
- Tools necessary to perform the repairs.
- A computer equipped with Alldata's reference repair manuals.
- An office equipped with a phone.

Mechanic Selection

The original intent of the I&M Pilot Program was to recruit licensed Smog Check mechanics, currently working in local Smog Check stations, to perform the repairs. Despite repeated attempts, CARB staff were unsuccessful in recruiting mechanics to participate in the six month program. Therefore, CARB recommended the use of BAR employed licensed Smog Check mechanics. The USEPA agreed to this change.

The repair phase of the program utilized two teams of mechanics. One team was responsible for repairing failed IM240 vehicles, while the other team was responsible for repairing failed ASM vehicles. Prior to establishing the repair teams, approximately two weeks were spent in training the mechanics on how to safely perform the repair grade IM240 (RG240) and ASM tests. Additionally, the mechanics viewed ASPIRE's video course on vehicle diagnosis, and were given a set of ASPIRE repair manuals. The mechanics were also instructed on how to record the repairs, and how to interpret the emission cutpoint tables provided to them. The mechanics were asked to repair the vehicles until the emission levels were below the applicable standards or the repair costs exceeded $500. In instances where the repair costs would exceed $500 the mechanics were asked to treat CARB as a client, and request permission for further repairs. The USEPA was responsible for assigning the repair teams to the IM240 and ASM bays.

Establishment of Cutpoints

The cutpoints used to pass or fail a vehicle in the I&M Pilot Program were based on the test data collected in a previous CARB study which compared the excess emissions identification rates and failure rates between the IM240, ASM5015 and ASM2525 tests. The report entitled "Assessment of Acceleration Simulation Mode (ASM) Testing As An Alternative To The IM240 Transient Dynamometer Test", details the results from that study. In that study, FTP, IM240, ASM5015 and ASM2525 data were collected on 174 vehicles randomly procured from CARB's ongoing testing programs. The dataset was grouped into 1981 and newer, 1975-1980, and 1974 and later model year vehicles. Regression equations, describing the relationship between the FTP composite emissions and each test type, by pollutant, were determined for each model year group of vehicles. These regression equations in conjunction with the FTP emission levels,** shown in Table 1, were used in determining the predicted cutpoints at a 2.5% error of commission rate

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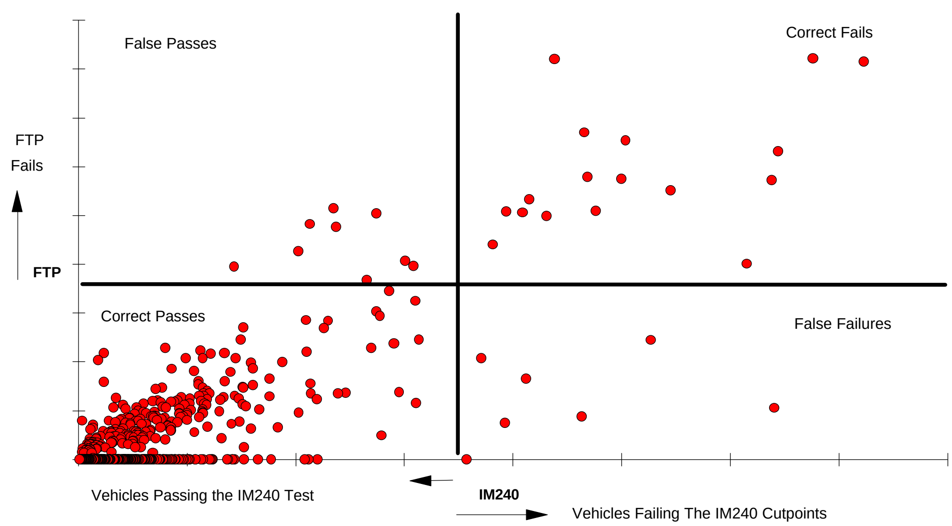
* The Clayton repair facility is located approximately two miles from CARB's El-Monte Laboratory.

** In order to identify a failing vehicle, the FTP emissions level were defined at twice the highest certification standard within each model group. For example, in the 1981 and newer model year group the highest certification standard for HC, CO and NOx is 0.41 g/mi, 7.0 g/mi and 0.7 g/mi, respectively. Therefore, for each pollutant. These predicted cutpoints were modified for use in this program to minimize the number of vehicles falsely failed, and to account for the accuracy of the BAR90 (TAS) analyzers in measuring raw emissions during the ASM tests. The predicted cutpoints, in conjunction with the regression equations for each model year group, were used to develop the final cutpoints. Figure 2 illustrates the philosophy used in developing the cutpoints. For a given FTP emission level, which is based on twice the highest certification level in a given model year group, one would ascertain the corresponding ASM or IM240 level which would minimize the false failures. Figure 2 also shows how the vehicles were categorized based on their screening test results.

Table 1 FTP Emissions Levels Used In Identifying Failing Vehicles

Model Year Grouping	HC g/mi	CO g/mi	NO g/mi
1981 & Newer Model Year	0.82	14.00	1.40
1975-1980 Model Year	1.80	18.00	4.00
1974 & Earlier Model Years	6.40	78.00	8.00

Figure 2 Categorization Of Vehicles Based On Their Initial Test Results



VEHICLE CAPTURE RATE

To balance the concerns of testing a representative fleet of vehicles with the practical issues of time available for testing and the geographic limitations on vehicle procurement, vehicles which were due for a Smog Check were randomly selected from a 25 mile radius of CARB's HSL. A list of zip codes within this 25 mile radius were sent to the Department of Motor Vehicles (DMV) which then provided a tape listing all registered passenger cars, light-duty trucks and medium-duty gasoline fueled vehicles that were due for a Smog Check between the months of July and December of 1994, and resided within the zip codes provided to DMV. The DMV's tape contained information on 1,392,684 vehicles. From this list, 2,000 vehicles were selected at random and then sorted by the registration due date. The first 300 vehicle owners with registrations expiring the following month were notified by mail to bring their cars in for testing. During the course of this program, a total of five mailings were done resulting in 1,500 vehicles being solicited.

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the FTP standard for this model year group was defined at 0.82 g/mi for HC, 14.0 g/mi for CO and 1.4 g/mi for NOx.

Capture Rate

The capture rate is defined as a ratio of the total number of vehicles procured for testing to the total number of vehicles available for testing. Historically, CARB's light-duty vehicle surveillance programs have averaged a capture rate between 4-15.7 percent.* Recognizing the importance of obtaining a high capture rate, CARB requested that participation in the I&M Pilot Program be made mandatory. This requirement was incorporated into California's Senate Bill 2018 which gave the authority to conduct the I&M Pilot Program. Additionally, participants were offered incentives that included payment of their vehicle registration fees which averaged $147.67, a full tank of gas, repairs, and if necessary the use of a rental vehicle. These incentives, with the exception of registration fees, are similar to those offered to participants in previous CARB surveillance programs. In previous programs, participants were offered $75-$100 as a cash incentive in place of registration fees.

From the 1,500 solicitation letters mailed, 642 vehicles were procured for testing at the CARB's HSL. Another 444 vehicles were excused from the testing program because they had already undergone a Smog Check test, the vehicle was sold or the letter was undeliverable. Accounting for vehicles dismissed, the overall capture rate achieved was 60.8%. The capture rate is calculated as: (642/(1500-444))*100%.

Representativeness

An important aspect of random sampling is determining how well the random sample of vehicles procured for testing compares to the population of vehicles from which it was selected. In this case, the population is defined as those vehicles in DMV's 1,392,684 vehicle dataset. However, in this procurement process there were two random samples to consider. The first random sample consisted of the 1,500 vehicles solicited for testing. The second sample consisted of the 642 vehicles procured for testing. In order to determine if the sample of vehicles procured for testing was representative of the population of vehicles they were selected from, vehicle identification numbers (VIN) from the DMV's listing,** the 1,500 vehicles solicited for testing and, the 642 vehicles procured for testing were analyzed using Radian Corporation's VIN decoder (Version 1.0) program. This program decodes the VIN to provide information on the make, model year, vehicle class, technology type (carbureted and fuel-injected) and if the vehicle is equipped with a catalyst. Of the 40,529 vehicles in the DMV listing, the 1,500 and the 642 vehicle datasets, VINs from 36,414, 1,325 and 554 vehicles from the respective datasets were analyzed by the VIN decoder. The main difference in size between the actual vehicle datasets and the analyzed datasets can be attributed to the VIN decoder's ability to only decode VINs from 1972 and newer model year vehicles.

Figure 3 shows the comparison of the model year distributions from the DMV listing, the 1,500 and the 642 vehicle datasets. The mean model year of the vehicles from these datasets are 1985.26, 1985.30 and 1985.94, respectively. Please note, the true mean of the datasets will be different to that shown here since only 1972 and newer vehicles were analyzed, however, the results would not change significantly if 1971 and older model year vehicles were analyzed because these vehicles are a smaller percentage of the overall fleet.

* The highest capture rate was achieved in Light-Duty Vehicle Surveillance 12 program. Prior to this program, the capture rate varied between 4 and 8 percent.

** Due to the size of DMV's dataset (1,392,111), VINs from 40,529 vehicles were analyzed using the VIN decoder program.

Figure 3 Comparison Of Model Year Distributions From The DMV Listing, 1,500 Vehicles Solicited And The 642 Vehicle Datasets

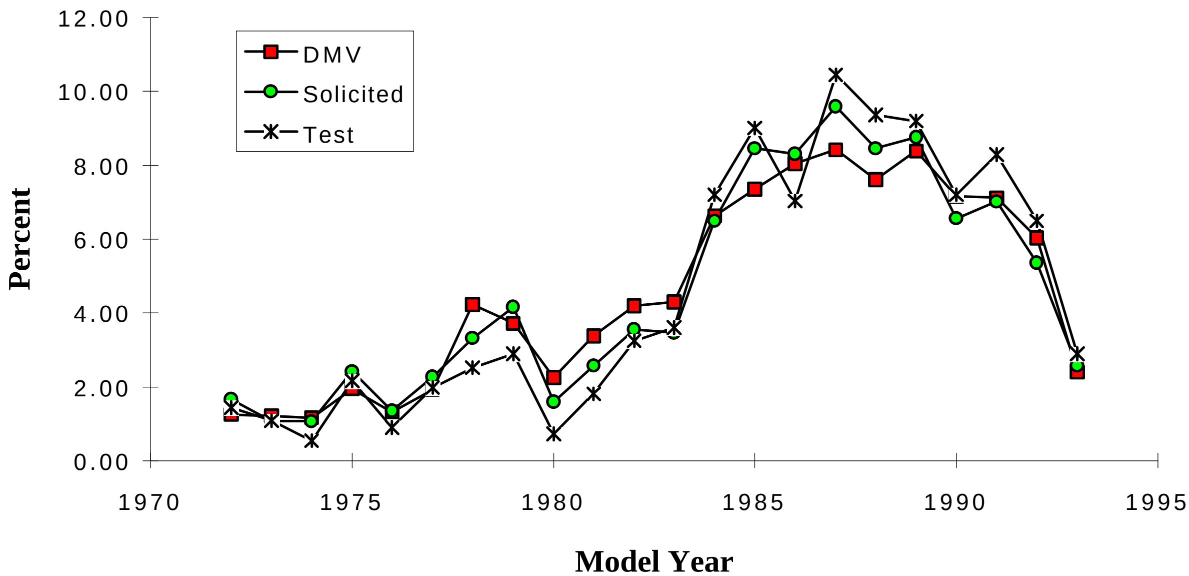


Figure 3 shows that there are no significant differences between the model year distributions from the DMV listing, the 1,500 and the 642 vehicle datasets; implying that there are no biases in CARB's procurement process. Figures 4 and 5 show the model year distributions of all carbureted and all fuel-injected vehicles, respectively. These figures also indicate that there are no significant differences in the model year distributions of carbureted and fuel-injected vehicles procured for testing to the distributions found in the general population of vehicles.

Figure 4 Comparison of Model Year Distributions For Carbureted Vehicles In The DMV Listing, 1,500 Vehicles Solicited And The 642 Vehicle Datasets

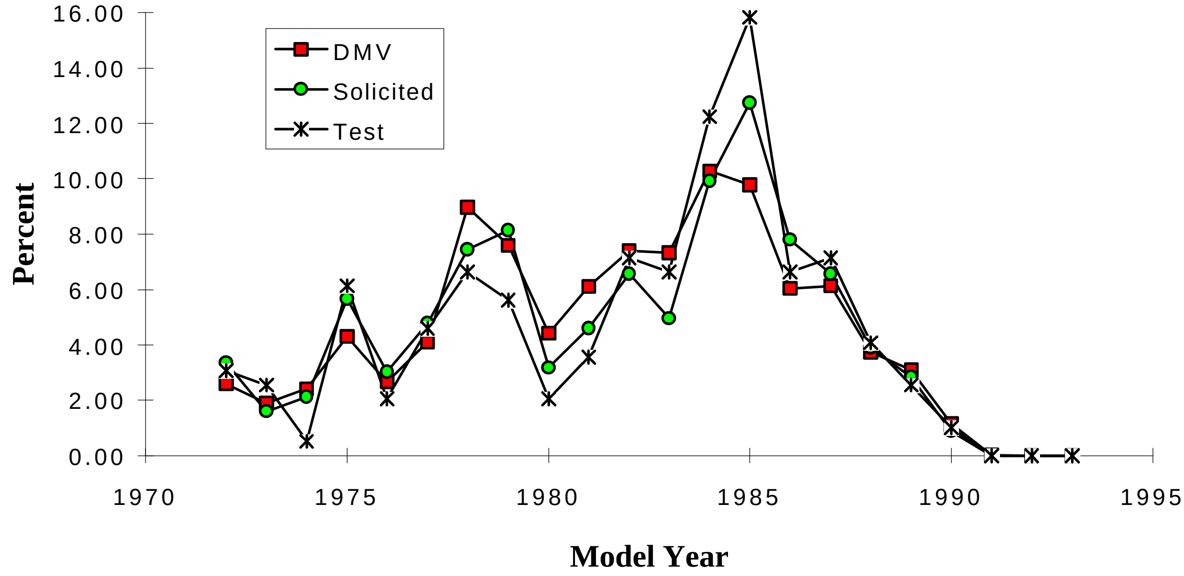
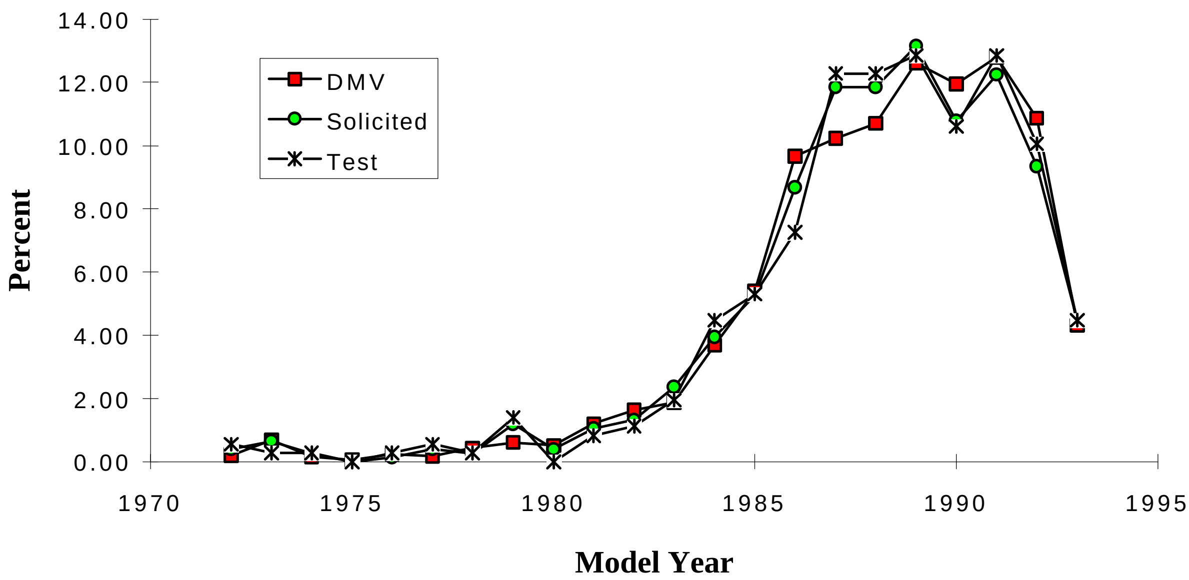


Figure 5 Comparison of Model Year Distributions Of Fuel-Injected Vehicles In The DMV Listing, 1,500 Vehicles Solicited And The 642 Vehicle Datasets



To further verify this visual interpretation of the results, a chi-squared tests (X^2) was performed (at a 95% confidence level) to determine if the observed model year distributions from all vehicles is significantly different than the expected model year distribution from all vehicles. The results indicate that the three distributions of vehicles, by model year and technology group, are the same and the sample of vehicles procured for testing was representative in terms of model years to the general population of vehicles.

IDENTIFICATION RATES

Table 2 shows the number of vehicles that were initially classified as EC, EO, CF, CP for each of the screening tests, and by model year. This table shows that without any adjustments (for EC and EO), the IM240 and ASM tests correctly fail 199 and 204 vehicles, respectively. In comparison, the BAR90 test for emissions failed only 118 vehicles, and falsely passed (EO) 7 more vehicles than it correctly failed. When visual and functional tests are taken into account, the overall BAR 90 test failed 185 vehicles and falsely failed 105 vehicles.

Tables 3 and 4 shows the average emission rates (g/mi) for vehicles that received an FTP test, from all vehicles and for 1981 and newer model year vehicles, respectively. These tables show the average emission rates for vehicles categorized as EC, EO, CF and CP for each of the baseline tests performed on the vehicles. Please note, these tables contain statistics for vehicles that received an FTP test, and inferences on the overall statistics cannot be made without taking into account the entire fleet of vehicles tested.

Table 2 Number of Vehicles Classified As EC, CF, EO And CP For Each Test

Model	IM240				5015				2525				ASMS				BAREXST			
Year	EC	CF	EO	CP	EC	CF	EO	CP	EC	CF	EO	CP	EC	CF	EO	CP	EC	CF	EO	CP
66	1			4	1			4	1			4	1			4	1			4
67		1		1		1		1		1		1		1		1		1		1
68		3		2	1	2	1	1		2	1	2	1	2	1	1	2	2	1	
69		3				2	1			2	1			2	1			2	1	
70		2		5		1	1	5		2		5		2		5		1	1	5
71	1	1		1			1	2			1	2			1	2			1	2
72	1	4				3	1	1		2	2	1		3	1	1	1	3	1	
73	1	2		6		1	1	7		1	1	7		1	1	7	3	1	1	4
74	2	1		2	2		1	2			1	4	2		1	2	2		1	2
75	1	3			1	3			1	3			1	3			1	2	1	
76		7	1	1	1	7	1			8		1	1	8				4	4	1
77	1	14		3	1	10	4	3		10	4	4	1	10	4	3	2	7	7	2
78	2	8	2			9	1	2		10		2		10		2	1	6	4	1
79	3	7	1	4	1	5	3	6	2	6	2	5	2	6	2	5	1	4	4	6
80		6		5	1	6		4	2	5	1	3	2	6		3		4	2	5
81	1	5		4	2	5		3	1	5		4	2	5		3	2	3	2	3
82		14	1	2		14	1	2		15		2		15		2		7	8	2
83	2	16	3	2	1	14	5	3		15	4	4	1	16	3	3		8	11	4
84	1	25	7	8	3	27	5	6	3	28	4	6	4	29	3	5	1	16	16	8
85	2	29	9	17	4	27	11	15	3	27	11	16	4	30	8	15	2	18	20	17
86	4	16	6	16	4	17	5	16	4	16	6	16	4	18	4	16	3	9	13	17
87	5	17	2	33	4	15	4	34	4	14	5	34	5	15	4	33	4	10	9	34
88		7	5	42	1	7	5	41		7	5	42	1	9	3	41	3	4	8	39
89	5	7	1	43	2	7	1	46	4	7	1	44	4	8		44	1	4	4	47
90	1		3	38	3	1	2	36	1	2	1	38	3	2	1	36	1		3	38
91	1		1	45	2	1		44	1		1	45	3	1		43	1		1	45
92		1	2	36	1	2	1	35		2	1	36	1	2	1	35	1	2	1	35
93				18				18	1			17	1			17				18
94																				
Total	35	199	44	338	36	187	56	337	28	190	53	345	44	204	39	329	33	118	125	340
Percent	5.68	32.31	7.14	54.87	5.84	30.36	9.09	54.71	4.55	30.84	8.60	56.01	7.14	33.12	6.33	53.41	5.36	19.16	20.29	55.19

Table 3 Average Emission Rates (g/mi) For All Model Year Vehicles

TEST		No. Vehs	Percent	FTWT_HC	FTWT_CO	FTWT_NOX
IM240	EC	25	6.54	1.722	23.012	2.115
	CF	199	52.09	4.843	49.362	2.181
	EO	44	11.52	1.227	17.464	1.352
	CP	114	29.84	0.580	7.612	0.807
5015	EC	22	5.76	1.605	21.476	1.797
	CF	187	48.95	4.592	48.306	2.066
	EO	56	14.66	2.842	27.828	1.912
	CP	117	30.63	0.631	8.295	0.901
2525	EC	17	4.45	0.961	14.298	1.756
	CF	190	49.74	4.593	47.255	2.167
	EO	53	13.87	2.738	30.435	1.542
	CP	122	31.94	0.761	9.836	0.943
ASM	EC	29	7.59	1.353	18.257	1.631
	CF	204	53.40	4.426	46.212	2.101
	EO	39	10.21	2.946	29.857	1.666
	CP	110	28.80	0.636	8.305	0.888
BAREXST	EC	18	4.71	2.249	26.465	2.124
	CF	118	30.89	6.589	62.825	1.988
	EO	125	32.72	1.922	25.426	2.072
	CP	121	31.68	0.567	7.989	0.882

Table 4 Average Emission Rates (g/mi) For 1981 and Newer Model Year Vehicles

TEST		No. Vehs	Percent	FTWT_HC	FTWT_CO	FTWT_NOX
IM240	EC	14	4.83	0.481	7.848	0.765
	CF	137	47.24	2.453	35.007	1.994
	EO	40	13.79	0.846	11.927	1.244
	CP	99	34.14	0.324	5.232	0.610
5015	EC	14	4.83	0.420	7.669	0.868
	CF	137	47.24	2.387	34.094	1.922
	EO	40	13.79	1.073	15.054	1.489
	CP	99	34.14	0.332	5.258	0.597
2525	EC	12	4.14	0.438	7.564	0.853
	CF	138	47.59	2.411	33.775	1.965
	EO	39	13.45	0.956	15.694	1.325
	CP	101	34.83	0.332	5.318	0.603
ASM	EC	19	6.55	0.412	7.298	0.816
	CF	150	51.72	2.293	32.190	1.907
	EO	27	9.31	0.962	16.464	1.363
	CP	94	32.41	0.329	5.204	0.592
BAREXST	EC	9	3.10	0.447	6.648	1.009
	CF	81	27.93	3.375	48.542	1.702
	EO	96	33.10	1.006	13.970	1.928
	CP	104	35.86	0.334	5.462	0.597

These statistics were re-weighted to account for the fact that not all vehicles received a baseline FTP. The following example illustrates how the EC, EO, CF and CP rates were recalculated, to account for the entire fleet of vehicles tested, for the IM240 test. Table 5, reproduced here from Table 2, shows the unadjusted statistics for the IM240 test.

Table 5 Unadjusted Statistics For The IM240 Test

IM240 Test							
EC		CF		EO		CP	
No	%	No	%	No	%	No	%
35	5.68	199	32.3	44	7.14	338	54.87

The total number of vehicles that passed the IM240 test is 382. Of these vehicles there are FTP data on 158 vehicles of which 44 vehicles failed the FTP test. The omission rate is (44/158) 27.85%. This omission rate is then applied to the fleet of vehicles that passed the IM240 test, and did not receive an FTP test. Therefore, the number of vehicles that are determined to be errors of omission is 106, e.g. 44+0.2785*(382-158). The number of vehicles that are true passes=382-106=276. Similarly, the number of vehicles that failed the IM240 test is (199+35)=234. Of these vehicles there is FTP data on 224 vehicles of which 199 vehicles failed the FTP test. The failure rate is (199/224)=88.84%. This failure rate is then applied to the fleet of vehicles that failed the IM240 test, and did not receive an FTP test. Therefore, the number of vehicles that are correctly failed=199+0.8884*(234-224)=208. The number of vehicles that are errors of commission=35-0.8884*(234-224)=26. Table 6 shows the adjusted number of vehicles that are EC, CF, EO and CP. Table 7 shows the adjusted identification rates by test and model year. The excess emissions were also similarly weighted to calculate the percent of excess emissions identified. Table 8 shows the corresponding percentage of excess emissions identified by each test.

Table 6 Adjusted Statistics For The IM240 Test

IM240 Test							
EC		CF		EO		CP	
No	%	No	%	No	%	No	%
26	4.22	208	33.77	106	17.27	276	44.74

Table 7 Relative Identification Rates By Test and Model Year

All Model Year Vehicles	Errors Of Commission		Correct Fails		Errors Of Ommission		Correct Passes		Total Number Of Vehicles
	N	%	N	%	N	%	N	%	
IM240	26	4.22	208	33.77	106	17.21	276	44.81	616
ASM5015	23	3.73	200	32.47	127	20.62	266	43.18	616
ASM2525	18	2.92	200	32.47	121	19.64	277	44.97	616
Both_ASMs	31	5.03	217	35.23	96	15.58	272	44.16	616
BAR_Exst	20	3.25	131	21.27	236	38.31	229	37.18	616

1981 and Newer Vehicles	Errors Of Commission		Correct Fails		Errors Of Ommission		Correct Passes		Total Number Of Vehicles
	N	%	N	%	N	%	N	%	
IM240	15	2.98	144	28.63	99	19.68	245	48.71	503
ASM5015	15	2.98	151	30.02	93	18.49	244	48.51	503
ASM2525	13	2.58	147	29.22	96	19.09	247	49.11	503
Both_ASMs	21	4.17	162	32.21	71	14.12	249	49.50	503
BAR_Exst	10	1.99	90	17.89	193	38.37	210	41.75	503

1980 and Older Vehicles	Errors Of Commission		Correct Fails		Errors Of Ommission		Correct Passes		Total Number Of Vehicles
	N	%	N	%	N	%	N	%	
IM240	11	9.73	64	56.64	8	7.08	30	26.55	113
ASM5015	8	7.08	51	45.13	25	22.12	29	25.66	113
ASM2525	5	4.42	53	46.90	22	19.47	33	29.20	113
Both_ASMs	10	8.85	55	48.67	21	18.58	27	23.89	113
BAR_Exst	10	8.85	41	36.28	39	34.51	23	20.35	113

Table 8 Percent Of Excess Emissions Identified By Each Test

All Model Yr. Vehicles	Percent Of Excess Emissions Identified		
	Hydrocarbons	Carbon Monoxide	Oxides Of Nitrogen
IM240	96.15	94.29	90.63
ASM5015	80.11	86.48	76.28
ASM2525	81.19	82.98	87.77
Both_ASMs	84.56	89.48	89.24
BAR_Exst	78.54	71.19	31.36

1981 Newer Vehicles	Percent Of Excess Emissions Identified		
	Hydrocarbons	Carbon Monoxide	Oxides Of Nitrogen
IM240	93.61	95.56	89.45
ASM5015	86.56	88.07	76.92
ASM2525	91.08	87.22	85.72
Both_ASMs	92.80	89.21	86.82
BAR_Exst	78.62	81.27	27.74

1980 Older Vehicles	Percent Of Excess Emissions Identified		
	Hydrocarbons	Carbon Monoxide	Oxides Of Nitrogen
IM240	97.88	93.98	100.00
ASM5015	81.62	87.88	69.30
ASM2525	81.71	83.31	100.00
Both_ASMs	83.95	91.03	100.00
BAR_Exst	83.22	86.64	63.16

Table 7 shows that overall, the ASM tests correctly fails more vehicles than the IM240 test. The difference in failure rates can be accounted for by the difference in EC rates between the IM240 (EC rate 4.22%) and ASM (EC rate 5.03%) tests.

Table 8 shows that although the ASM tests failed the same number of vehicles as the IM240 test, overall they identify slightly less of the excess emissions. Compared to the IM240, the ASM tests are 87.95%, 95.90% and 98.47% effective in identifying the excess HC, CO and NOx emissions, respectively. For 1981 and newer model year vehicles, the ASM tests are 99.13%, 93.35% and 97.06% as effective as the IM240 test in identifying excess HC, CO and NOx emissions, respectively. For 1980 and older model year vehicles, the ASM tests are 85.47%, 96.86% and 100.00% as effective as the IM240 test in identifying excess HC, CO and NOx emissions, respectively.

Prior to this Pilot Program, there was considerable debate as to whether ASM tests could identify malperforming newer technology vehicles since the these tests were regarded in the same light as idle tests in their ability to identify failures in newer technology vehicles. Figures 6 and 7 show the percent of carbureted and fuel-injected vehicles failing each exhaust emissions test, respectively. Chi-square tests were performed on both the carbureted and fuel-injected vehicle distributions to ascertain if there was a significant difference in the distribution of vehicles failed by the ASM and IM240 tests. The results indicate that for both carbureted and fuel-injected vehicles there is no difference in the distribution of vehicles failing each test, indicating that ASMs can identify failures in newer technology vehicles as well as the IM240 test.

Figure 6 Percent Of Carbureted Vehicles Correctly Failed For Exhaust Emissions, By Test

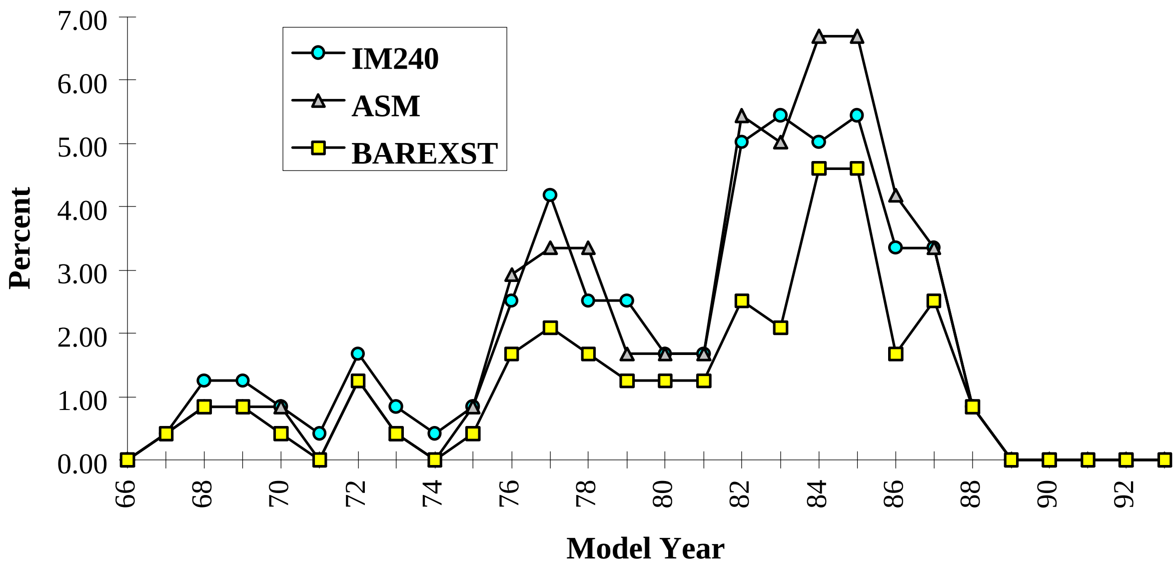
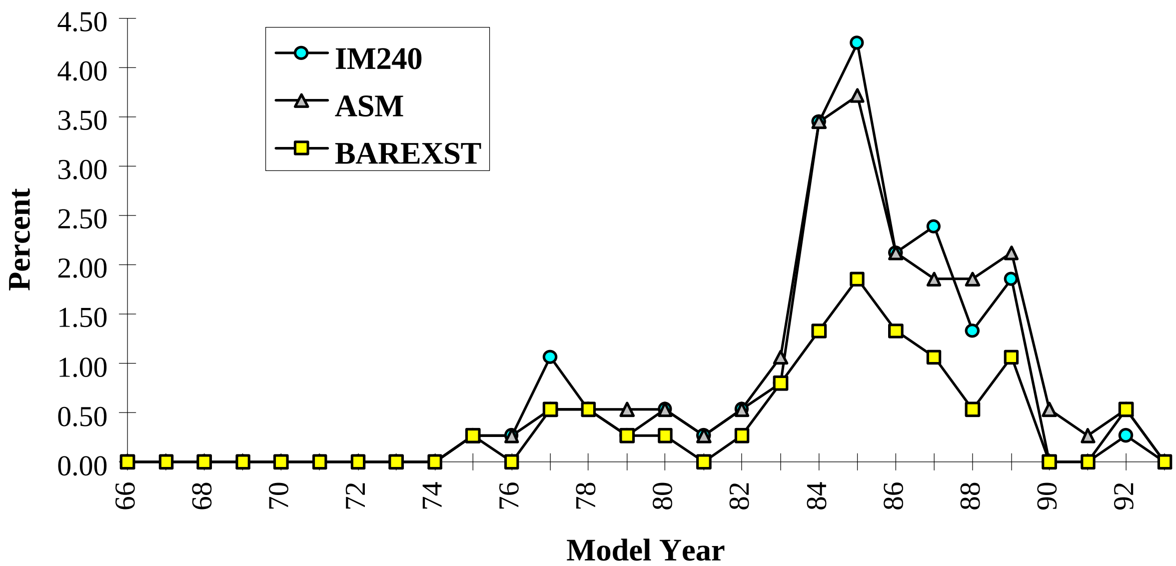


Figure 7 <u>Percent Of Fuel-Injected Vehicles Correctly Failed For Exhaust Emissions, By Test</u>



EMISSION REDUCTIONS

One of the goals of the I&M Pilot Program was to assess the repair effectiveness of the IM240 and ASM tests, that is, if a vehicle can be repaired to pass either the IM240 or ASM cutpoints such that its emissions are below the levels defined in Table 1. The USEPA believed that the steady-state nature of the ASM test will make it easier for mechanics to falsely pass a vehicle using the ASM cutpoints, resulting in a potential reduction in the repair effectiveness of the ASM tests. In addition, the USEPA believed the IM240 test will enhance the mechanic's ability in diagnosing and repairing vehicles whereas the ASM tests will not. Please note, the repair phase of the program was not designed to evaluate the repair effectiveness of the BAR 90 test.

There were 107 and 97 vehicles assigned to the ASM and IM240 bins, respectively. Of the 107 vehicles assigned to the ASM bin, 16 were falsely failed and 91 were correctly failed by the ASM tests. Conversely, 1 was falsely failed, 19 were falsely passed, 15 were correctly passed and 72 were correctly failed by the IM240 test. Of the 97 vehicles assigned to the IM240 bin, 17 were falsely failed and 80 were correctly failed by the IM240 test. Conversely, 4 were falsely failed, 19 were falsely passed and 61 were correctly failed by the IM240 test. Table 9 shows the repair status for vehicles assigned to the ASM and IM240 bin.

Table 9 Repair Status For Vehicles Assigned To The ASM and IM240 Bins

BIN	Repair Status	EC	CF	Total
ASM	No Repairs	7	20	27
	Partial Repair	2	19	21
	Full Repair	7	52	59

BIN	Repair Status	EC	CF	Total
IM240	No Repairs	12	13	25
	Partial Repair	0	8	8
	Full Repair	5	59	64

Of the 27 vehicles that were not repaired in the ASM bin, 21 were not repaired because they passed the baseline test at the Clayton repair facility, an additional 6 vehicles were not repaired because the mechanics believed that these vehicles could not be repaired with the $500 repair cost limit. The mechanics referred to these vehicles as "*junkers*". Of the 25 vehicles that were not repaired in the IM240 bin, 23 were not repaired because they passed the baseline test at the Clayton repair facility, and 2 vehicles could not be repaired within the $500 repair cost limit. Of the 107 vehicles in the ASM bin, 21 were partially repaired by the mechanics. Further repairs on these vehicles would have exceeded the repair cost limit. Similarly, of the 97 vehicles assigned to the IM240 bin, 8 were partially repaired by the mechanics. Please note, the $500 repair limit was only applicable to fixing defective components, and there was no monetary limit placed on fixing tampered components. Table 10 shows the percent excess emissions reduced overall, and the percent of excess emissions reduced for vehicles that were fully repaired. These results indicate that vehicles can be successfully repaired to the either the ASM or IM240 standards, and that the repair effectiveness of both tests is similar. This finding contradicts the perceived deficiencies of the ASM tests which assumed that vehicles would not be correctly repaired using the ASM test cutpoints. A commonly used analogy compared the ASM tests to the current BAR90 idle tests where simple engine adjustments could be used to pass the test. The results from this program indicate that simple fixes are not sufficient to pass the ASMs primarily because the vehicle must pass the emission test cutpoints for all three pollutants.

Table 10 Percent Of Excess Emissions Reduced Overall And For Fully Repaired Vehicles

OVERALL			
BIN	Hydrocarbons	Carbon Monoxide	Oxides Of Nitrogen
IM240	77%	62%	84%
ASM	78%	77%	86%
FULLY REPAIRED VEHICLES			
BIN	Hydrocarbons	Carbon Monoxide	Oxides Of Nitrogen
IM240	88%	84%	93%
ASM	77%	84%	96%

REPAIR COSTS

In this program three types of repairs were performed: repairs necessary to prepare a vehicle for dynamometer testing “pre-acceptance repairs,” repairs at CARB’s Clayton repair facility to reduce excessive emissions, and post-program repairs to redress alleged vehicle performance problems caused by the program.

Pre-Acceptance Repairs

The CARB’s past experience with dynamometer testing has shown that is necessary to replace worn tires, leaking radiators, dead batteries, poor brakes, bad steering or wheel alignment, leaking exhaust systems, and perform other repairs that may affect the accuracy of emissions measurements or the safe testing of a vehicle on a dynamometer. These repairs help to minimize the number of driving violations occurring within each test and reduce the chances of aborting a test.

Table 11 shows the average per vehicle cost for each component repaired. The most expensive repairs were performed to correct defective brakes. These repairs were necessary to ensure that the vehicles can perform a transient test without incurring violations and safely stop a vehicle. The most frequent repairs were performed to repair leaking exhaust systems. Again, this was a safety repair to prevent a high CO background in the repair bay, and also to ensure accurate measurement of emissions. Of the 643 vehicles tested in the Pilot Program, 177 vehicles required repairs (in some cases multiple repairs) prior to testing at an average cost of $204. It was the judgment of CARB mechanics to replace bad batteries in order to prevent any start-up problems that may occur in the subsequent phases of the program. If these vehicles (18 vehicles had battery repairs only) are removed then the average per vehicle cost is $217. It is anticipated that some vehicle owners are likely to incur this cost in order to safely test their vehicles on a dynamometer.

Table 11 Average Per Vehicle Pre-Acceptance Repair Cost

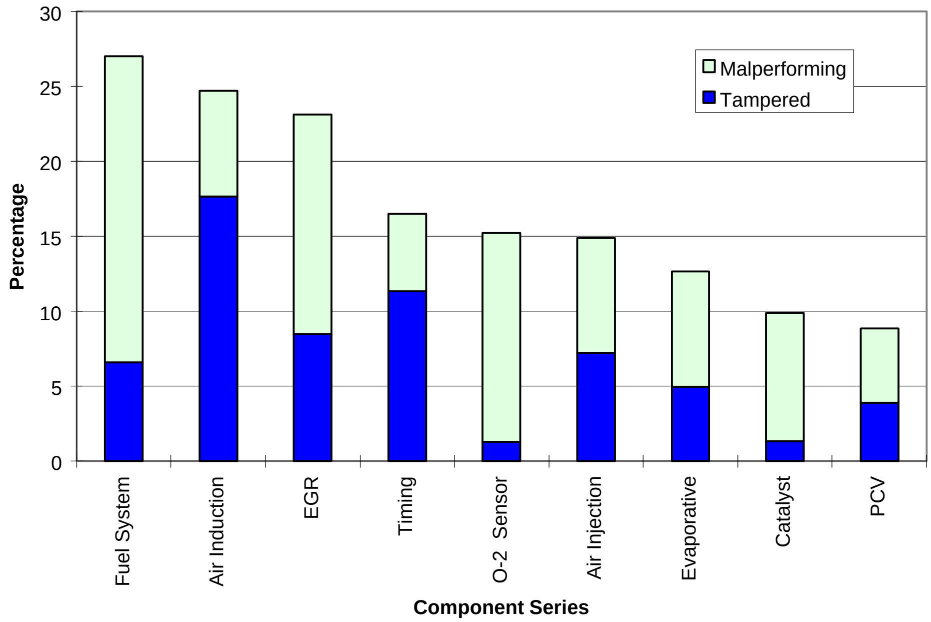
Component Repaired	Number	Total Cost $	Per Vehicle Cost $
Tires	10	1,582	158
Radiator	7	2,897	414
Battery	28	1,537	55
Brakes	16	6,800	425
Steering	1	113	113
Exhaust	125	21,094	169
Other	21	2,072	99
OVERALL		36,095	

Repairs Costs *to reduce excess emissions*

This reflects the actual cost to reduce the vehicle’s excess emissions. A labor rate of $40 per hour was used in estimating the overall repair cost. The labor hours were estimated using the Alldata software system to avoid an unrealistic amount of time spent in diagnosing vehicle problems. Additionally, there was no limitation on the amount spent in fixing tampered components. Figure 8 shows the percentage of malperformance and tampering by emission component systems for vehicles so equipped. Emission related systems that are missing, modified or disconnected are defined as being tampered. The definition of malperforming includes tampered components and otherwise defective components.

Figure 8 shows that about 27% of vehicles were identified as having malperforming fuel systems of which 6.6% of the total were tampered. It was found that 24.7% of those vehicles equipped with an air induction system were malperforming and 17.6% were tampered. Less than 10% of the vehicles equipped with catalysts and PCV systems were malperforming. The most tampered components were the air induction systems and vehicle timing, while the least tampered components were O2 sensors and catalysts.

Figure 8 Percentage Of Malperformance By Emission Component Systems

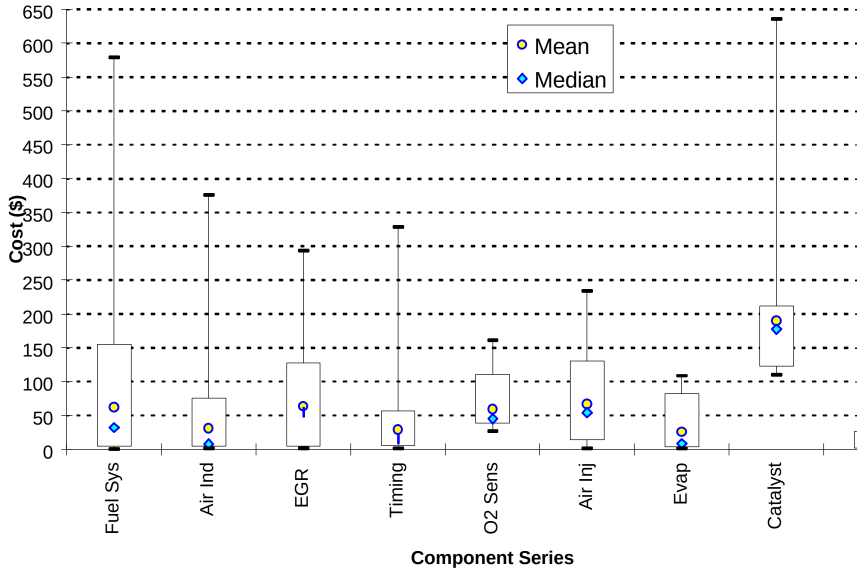


A database containing the parts used for repairs and their purchase price was analyzed to ascertain for each system component: the mean cost, the maximum and minimum costs, the median cost, and the 10th and 90th percentile cost values of parts needed for repairing malperforming systems. The distribution of costs by system component is shown in Figure 9 as a box-whisker chart. This analysis accounts only for the costs of parts used for repairs and excludes the costs of any labor required to replace those components. It should be noted that the parts were purchased from local stores which were available to the Clayton mechanics at the time of repairs, and not all parts purchased were new.

Based on the results shown in Figure 9, it is apparent that catalyst repairs are the most expensive with an average cost of about $190 per replacement, and a maximum cost of about $636 (i.e., an OEM catalyst for a 1985 Ford Mustang). For this component, the box-whisker chart shows a minimum cost of $110, a median cost of about $177, a 90th percentile cost of $212 and a 10th percentile cost of $123. These findings imply that motorists should expect to spend at least $110 for catalyst replacement if their vehicle is diagnosed as needing this repair. Similarly, parts for a vehicle's fuel system may cost $62 on average with the high potential cost of about $580 (e.g., a carburetor for a 1978 Cadillac Coup DeVille). However, it is noted here that only 10% of the vehicles needing this repair show a parts cost exceeding $150.

Approximately 14% of the vehicles that failed the IM240 and ASM tests received partial repairs because further repairs would have exceeded the repair cost limit. Additionally, the mechanics did not attempt repairs on 8, or 3.9%, vehicles (referred by the mechanics as "*junkers*") that failed both the IM240 and ASM tests because repairs would have far exceeded the $500 cost limit. The average repair cost of fully repaired vehicles was $368.24 which includes $108.23 cost for tampering costs. The median cost for fully repaired vehicles was $243.30. Approximately 32.5% of the vehicles that were fully repaired were tampered. The average cost of only fixing tampering repairs was $327.

Figure 9 Replacement Costs For Emission Component Systems



Post Program Repairs

Vehicles repaired in the I&M Pilot Program were returned to their owners with a Smog Check certificate. However, some of the participants noticed a change in the performance of their vehicle or later experienced a system failure, such as engine misfiring or overheating. These participants contacted the program engineers to explain their vehicle problems and requested further repairs to correct alleged incorrect repairs. A total of 28 vehicles or 4% (28/643) returned for further repairs. The average cost to correct defects caused by the program was $97. In an actual I&M application, this cost would be incurred by either the motorist or the repair facility.

CONCLUSIONS

The significant findings of the Pilot Program are:

- Tables 8 and 9 show that the use of dynamometer based loaded mode testing (either the ASMs or IM240) will result in the increased identification and repair of malperforming vehicles when compared to the traditional idle tests.
- Figures 6 and 7 show that the ASM tests perform equally well as the IM240 test in identifying failing vehicles for both older and newer technology vehicles.
- Vehicles can be correctly repaired using the ASM emission test cutpoints. The results from this program indicate that simple fixes, sometimes used to pass the BAR 90 test, are not sufficient to pass the ASMs primarily because the vehicle must pass the emission test cutpoints for all three pollutants.
- Table 12 indicates that approximately 28% of the vehicle owners are likely to incur a significant one time cost to correct defects that will allow for safe and accurate dynamometer based emission tests.
- The benefits of emission reductions are derived primarily from proper repair, not from testing. It is, therefore, critical to provide the repair industry with the appropriate tools to replicate those tests performed at centralized, or test only stations to ensure effective repair. The mechanics who performed vehicle repairs testified to the California I&M Review Committee that they found the repair grade dynamometer and the capability to perform ASM tests at various loads very useful in diagnosing vehicles and verifying that the repairs were performed correctly.
- CARB staff believe that proper preconditioning of vehicles is essential in deriving accurate emission results regardless of which test procedure is adopted, and ensures more effective repairs and minimizes inconvenience to motorists. Statistical analyses, not detailed in this paper, indicates that there are significant differences between vehicles that were preconditioned versus those that were not preconditioned. For example, vehicles that were preconditioned were less likely to be falsely failed by either test.

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